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AN INVESTIGATION OF TIME-SHARING ABILITY AS A FACTOR IN COMPLEX--ETC(U)
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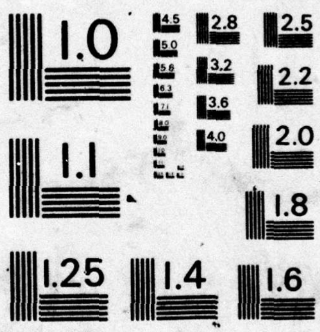

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AN INVESTIGATION OF TIME-SHARING ABILITY AS A FACTOR IN COMPLEX PERFORMANCE

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16. Abstract

Thirty-nine men were tested on a total of six tasks; performance was measured on each task presented individually and on two complex tasks made up of three-task subsets. The tasks measured monitoring, arithmetic, pattern-discrimination, tracking, and problem-solving performance. Two separate test sessions were conducted for each of the individual tasks and for each of the two complex tasks.

Factor analyses were performed on the resultant data to determine if there would merge a time-sharing ability, defined as a reliable source of variance associated with complex performance but independent of simple-task performance of the constituent tasks. A factor was found that showed high loadings for two different monitoring tasks for complex performance but negligible loadings for these tasks for simple performance; separate independent factors were found for the two monitoring tasks when they were performed under simple-task conditions. The monitoring measures appear to possess properties that would be expected of measures of a time-sharing ability. The findings suggest that a suitable measure of time-sharing ability would be of value in the selection and screening of candidates for complex jobs.

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AN INVESTIGATION OF TIME-SHARING ABILITY AS A FACTOR IN COMPLEX PERFORMANCE

I. Introduction.

People concerned with training personnel for complex jobs have long recognized that individuals differ with respect to the ease with which they are able to master multiple-element jobs and there are some complex jobs that some people cannot master. As stated by Chiles, Jennings, and West[7] on the basis of discussions with instructors at the Federal Aviation Administration (FAA) Academy, a number of trainees are eliminated from the air traffic controller training program, not because they lack specific academic or other skills, but because they are deficient in the concurrent performance of the variety of tasks of which the controller's job is composed. An analogous belief has been expressed by flight instructors about flying trainees.

Underlying these notions is the implicit hypothesis that the acquisition of skill on a complex task, considered in its entirety, somehow rests on the learning of task features that "emerge" when the component tasks are combined to produce the complex task. These notions also assume that the emergent features of a complex task are not only quantitatively but also qualitatively different from the sum of the requirements of the individual tasks. Thus, although the supporting evidence comes largely from anecdotal observation, the wide acceptance of the position that there are abilities (or, perhaps, *an* ability) specific to complex performance provides one reason for seeking to determine if, in fact, such a phenomenon exists and can be quantified.

Another line of reasoning also suggests the possible existence of such an ability. Knowles,[20] in considering the problem of workload measurement, describes a technique in which the performance levels maintained on auxiliary or secondary tasks are used to indicate the level of workload imposed by the performance of a primary task. In discussing this technique, Senders[26] lists several assumptions on which this methodological approach to workload measurement rests. Two of those assumptions are directly relevant to the purposes of this study: (1) the operator is a single-channel system, and (2) the channel has a fixed capacity. We interpret the concept of a single-channel system in this context to mean that an individual can do only one thing at a time. (For present purposes we will disregard the fact that some tasks can be learned to the extent that performance of such tasks can proceed more or less autonomously.) With this interpretation, it follows that if the operator is given two or more tasks to do "simultaneously," attention is shifted back and forth between tasks at a rate intended to insure adequate levels of performance on the individual tasks. The idea of a fixed-channel capacity simply means that there is a limit to the number of things the operator may be asked to do within a given set of time constraints without some degradation of performance on one or more individual tasks.

The secondary task approach was used by North and Gopher[22] in a study of performance in a divided attention task as a predictor of success in flight training. This study required subjects to perform a one-dimensional compensatory tracking task and a digit-processing reaction time task both individually and in combination. They found that measures of both tasks taken during complex performance discriminated reliably between "high-potential" and "low-potential" trainees, whereas measures taken during performance of the tasks singly did not. North and Gopher interpret their results as reflecting differences in the ability of the subjects to distribute their attention between the two tasks.

Thus far, the discussion has been concerned with complex performance as that term is used in operational contexts. We will now offer a somewhat more precise definition and will use the term in that manner in the remainder of the report. The term "complex performance" will be used to refer to performance situations in which the overall task is composed of a number of relatively independent task elements that are to be performed "simultaneously." Thus, in a complex-performance situation, the operator is required to divide his attention among a number of different displays or signal sources and respond to them more or less independently. There are three major ways that we might try to account for the overall level of skill exhibited in complex performance. First, it is possible that the overall level of performance is simply a function of skill on the constituent part tasks. Thus, the level of part-task skills would have a direct effect, in that good performance of any part tasks should contribute to an overall evaluation of performance. A second explanatory approach, derived from the first one, is that there should also be an indirect effect of part-task skill level, in that higher skill on a given part task would usually mean that the task can be accomplished in less time and thus more time would be available for attention to other part tasks. This second approach is one way of stating the basic rationale for the use of measures of secondary-task performance as indices of the workload imposed by a primary task;[20 25] that method assumes that consistent changes in the performance of a secondary task that are associated with systematic changes in the characteristics of a primary task may be interpreted as reflecting variations in the demands of the primary task even though no change is seen in the performance of the primary task itself.

The third approach suggests that there may be a *special* skill or ability involved in complex performance. The existence of such a skill would imply that there should be reliable individual differences in how well operators can "schedule" (time share) their work to minimize the interference between tasks independent of the skill levels exhibited on the component tasks. The mechanics of this process are no doubt quite complex, and there may be a number of abilities and skills that would contribute to such optimal scheduling. For the sake of simplicity, however, the present discussion of operational performance will use the general term "time-sharing ability" as though it represented a unitary concept.

Time sharing, as the term is used in the operational context, refers to the ability of the operator to shift attention rapidly from one part task to another and to return smoothly to an interrupted part-task performance. By implication, it also refers to the ability of the operator to schedule his time and make decisions as to the most efficient point to interrupt an ongoing performance. However, *scheduling* in this context does not imply any significant degree of advanced planning; this broader use of the term "scheduling" would perhaps be better used to refer to the development of complex-performance strategies, assignment of priorities, and the like.

Barlett[1] introduced a concept of timing in skill that is closely allied to the concept of time sharing, and Conrad,[10] in further refining the concept, proposed to define timing as that characteristic of skilled performance that tends toward creating the most favorable temporal conditions for response. Conrad then applied this definition in studies that examined the effect of temporal structure on missed signals[8] and response accuracy[9] in a multiple-dial monitoring task. He interpreted his results to suggest that the subjects tended to modify their response initiation in a way that gave them more time for their responses than they would have had if their responses had more exactly matched the signal series.

Later, Conrad[11] used the same multiple-dial device to study task pacing. In a self-paced condition, the subjects were allowed to continuously adjust (within limits) the average speed of pointer movement. Through these adjustments the subjects produced a significant decrease in the variability of the intersignal intervals as compared to the variability inherent in the fixed-pace condition. This decrease in signal variability was accompanied by a significant improvement in average response accuracy, but there were wide individual differences in the improvement scores. In further analyses, Conrad found that the amount of improvement cor-

related 0.92 with the amount of change the subject induced in the inter-signal interval variability. For some subjects, performance was actually worse under the subject-paced condition. It could be that these subjects were not able to develop a response strategy that made control of rate an advantage, and, therefore, controlling the rate of pointer movement simply became an additional workload with a resultant decrease in performance level. Although Conrad did not pursue the matter of individual differences, his finding of wide variations across subjects in the achievement of good timing is compatible with the notion that there may be an identifiable ability that is relevant to performance in situations involving time sharing.

Further evidence of relevance to the proposition that time sharing can be considered a separable ability is found in factor analytic studies of complex performance. One kind of study done in this area has been concerned with the changes that are seen in the apparent factorial composition of complex tasks as a function of the level of practice on the task. These studies have typically included repeated performance on some complex criterion task and performance on a battery of reference or predictor tasks. In general, it is found that, as practice continues, changes occur with respect to which particular reference tasks predict the performance on the complex task, and, in addition, there emerges a factor that is specific to the criterion task itself.[13] In discussing these findings, Fleishman[13 14] offers three hypotheses to account for the observed trends: (1) late-stage performance requires different abilities than does early-stage learning; (2) as psychmotor learning progresses, kinesthetic abiilty factors play an increasing role relative to spatial-visual abilities; and (3) the ability to integrate abilities or actions represents a separate individual difference variable. To these we would add the obvious hypothesis that the task-specific variance was simply variance that was not represented in the particular set of predictor tests used in the study. It should be noted that these hypotheses are not mutually exclusive. Parker[23] partially confirmed the appropriateness of the first hypothesis and Fleishman and Rich[15] partially confirmed the appropriateness of the second hypothesis. Parker and Fleishman[24] appeared to have subscribed to the appropriateness of the third hypothesis when they stated that ". . . if the criterion is known to require time-sharing activities, the reference battery should *contain tests designed to measure a hypothesized* general time-sharing ability."

The third line of evidence on the existence of a time-sharing ability is found in studies involving the relationship between whole-task and part-task performance. One such study was conducted by Fleishman,[12] who used a multi-dimensional pursuit-tracking apparatus with separate displays and controls for each dimension. In this study, the subjects were tested on three single-dimension conditions, three dual-dimension conditions, and the whole-task (three-dimension) condition. Fleishman concluded that the best predictors of total task and two-dimension subtask performance were other multiple-control subtasks and that the particular components involved in a multiple-control subtask were less important than the fact that simultaneous practice on the components had occurred. In addition, we performed a factor analysis of the data presented by Fleishman and found that two factors accounted for essentially all of the commonality. One of these factors had large loadings only on the single-task conditions, and the other had large loadings only on the dual- and whole-task conditions.

Freedle, Zavala, and Fleishman,[16] using a complex pursuit-tracking task, performed a similar study. A factor analysis we performed on their data yielded two main factors: a single-task control factor and a multiple-task control factor. A specific combination of one single task and one dual task provided the best predictor of whole-task performance, but the dual tasks did not exhibit the overall predictive advantage found in the earlier study by Fleishman.[12]

Although these factor analytic studies provide the best available evidence in support of the tenability of our hypothesized time- sharing ability, they are not definitive. The main problem is that the constituent tasks were of the same basic nature. On the other hand, it could be argued that if an ability with the general character of a time-sharing ability emerges with homogeneous task elements, then we have good

reason to believe that task elements involving disparate behavioral functions would also exhibit such properties.

The applicability to our problem of the work typified by Conrad on dial monitoring suffers in that the skill level on one task element has a very direct effect on the apparent difficulty of performing the second task. Thus, the Conrad findings are compatible with the time-sharing-ability hypothesis, and Bartlett's concept of timing in skill is closely allied, but the results of those studies cannot be held to substantiate the hypothesis.

Thus, we see that although the existence of a time-sharing ability is widely assumed in discussions of job requirements, definitive quantitative evidence of such ability is lacking. The methodology of factor analysis offers one approach to the development of the desired evidence. Within that context, the hypothesized time-sharing ability would be defined as *a reliable source of variance that contributes to performance of complex tasks but is independent of simple-task performance of the constituent tasks.* This is the definition of the concept *time-sharing ability* that we propose to use in this paper. The specific way in which this would be revealed in a factor analysis would be by the finding of an orthogonal factor with large loadings for some tasks (measures) when performed as a part of a complex task but small loadings on these same tasks (measures) when performed individually. This factor should also show large loadings on other tasks performed as a part of a different complex task.

The purpose of this study is to examine two different complex tasks by using the factor analytic method to determine whether any of the performance measures exhibit the above described statistical properties that could be construed as evidence of a time-sharing ability.

II. Method.

A. *Apparatus.* In this study, the testing was carried out by using the Civil Aeromedical Institute (CAMI) Multiple Task Performance Battery (MTPB). This test battery was designed to test and measure a variety of skills judged to be important to aircrew performance but it was not intended to be a simulator of any particular system.[4] The MTPB consists of five subject testing panels and associated programming and scoring circuitry. The panels contain the displays and response controls for six different tasks, each of which may be presented in isolation or in any combination of tasks. The six tasks are very briefly described in the following sections; see Chiles, Alluisi, and Adams[4] for a more complete description.

1. Warning lights. This is a choice reaction-time task involving monitoring of five green lights and five red lights. Under each light is a pushbutton switch. The green lights are normally on and the red lights are normally off; the subject is instructed to push the button under the light whenever a light changes state. Signals were introduced at randomly selected intervals with a mean intersignal interval of 30 seconds.

2. Meter monitoring. This task involves monitoring four meters mounted across the top of the subject panel. Normally, the meter pointers are moving at random around a mean vertical position. The subject responds to a shift in the mean position of the pointer by throwing the associated lever switch in the direction of the deflection. The signals are introduced at randomly selected intervals, with a mean intersignal interval of 1 minute.

3. Mental arithmetic. In the arithmetic task, the subject is required to add two numbers and substract a third number from the sum of the first two without using paper and pencil. The problem elements were numbers from 10 to 99, selected with the restriction that neither digit of the third number should be identical to the corresponding digit of either of the first two numbers. The arithmetic task is machine paced, and a new problem is presented every 20 seconds. Both response time and accuracy are measured on this task. Accuracy is determined as a percentage of all problems presented.

4. Pattern identification. The display for the pattern identification task is a screen on the lower left of the subject's panel. This screen consists of a six-by-six matrix of close-butted lights covered by a translucent panel. A standard pattern is presented for 5 seconds followed by 2-second presentations of two comparison

patterns. The subject must then decide if one, neither, or both of the comparison patterns were the same as the standard (first) pattern and indicate his answer by pressing the appropriate response button. Pattern-identification problems are presented at the rate of 1 every 30 seconds. Both accuracy and response time are kept on this task.

5. Group problem solving. This task involves short-term memory and skill at following a set procedure. Each subject has a single pushbutton switch and three feedback lights mounted in the center of his panel. The subjects' task is to discover the correct sequence in which to push these buttons. Each problem sequence is presented twice in succession. During the first presentation, the solution phase, the subjects must determine the solution sequence by following a standard trial-and-error search sequence. During the second presentation, or confirmation phase, the subjects reenter the previous solution from memory. Response times are recorded separately for the solution and confirmation phases. Response time is measured from the previous problem-solving event, either a problem introduction or a button push. In addition, accuracy in the confirmation phase is recorded as the proportion of correct to total responses.

6. Two-dimensional compensatory tracking. The display for the tracking task is an oscilloscope screen sitting on top of the subject's panel. The target on the screen is a dot of light about 1 mm in diameter. A varying amplitude disturbance is imparted to the target in each dimension; the subject attempts to counteract the disturbance by using the control stick to keep the dot at the center of the screen (as defined by two crosshairs scribed on the face of the sceen). The tracking task is scored by analog circuitry that accumulates integrated absolute error and integrated error-squared measures for the horizontal and vertical dimensions. Root-mean-square (RMS) error is computed from the error-squared measures, and a vector sum measure is computed by taking the square root of the sum of the measures of horizontal and vertical error squared. The rationale for using this vector sum score is that the integrated error measures represent average horizontal and vertical distance from the center of the screen. Therefore, the vector sum of these distances would represent the hypotenuse of the triangle defined by these horizontal and vertical distances.

B. *Subjects.* Thirty-nine subjects were tested in this study. All were paid, volunteer, college men in their twenties. The first 15 subjects were tested in groups of five. In the remaining six testing groups, there was one subject per group who either did not complete the experiment or never came as scheduled. In the groups containing four subjects, the experimenter took the place of the fifth subject in the group problem-solving task; (data from the experimenter are not included in the results).

C. *Procedure.* The six tasks available on the MTPB were divided into two groups of three tasks each to form two complex tasks of approximately equal difficulty. Task A consisted of warning lights, arithmetic, and group problem solving. Task B was made up of meters, pattern identification, and tracking. During training and part-task testing, the three tasks in a given set were always presented in the same order; lights, arithmetic, and problem solving for Task A and meters, pattern identification, and tracking for Task B. Figure 1 presents the test schedule observed by one group of subjects. On each day of testing, the subjects were tested on both sets of tasks. The presentation order of the two complex tasks was completely counterbalanced by days for the first eight groups of subjects. The presentation order for the ninth group was constructed to most nearly equalize the number of subjects receiving a given complex task order

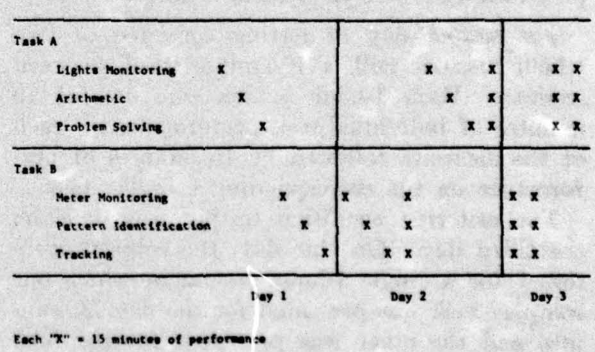

FIGURE 1. Test schedule—sample test group.

on a given day. All subjects were presented the same arithmetic, target identification, and problem-solving problems in corresponding sessions.

The training and testing of each group of subjects was caried out on three successive days, with each group of subjects always tested at approximately the same time of day. On the first, or training, day, the subjects were given a brief talk on the background of the MTPB and some examples of the sort of problems that had been investigated in the past on the MTPB. They were then told that the present study was an investigation of the relationship between simple and complex performance, and the testing schedule was explained to them. Then, they were given a procedural explanation of the tasks that they were to receive first on that day and were allowed to work a few sample problems on each element of one of the complex tasks while being closely monitored to determine that they were properly following the procedures involved. They were then tested in a single session in which they performed for 15 minutes on each of the three elements of that complex task. After a 10-minute break, they were given a similar explanation and testing session on the other complex task and were then excused for the day.

The second day of testing consisted of two 1-hour sessions with a 10-minute break between sessions. Each 1-hour session consisted of 15 minutes of individual-task performance on each of the elements followed by 15 minutes of performance on the corresponding complex task.

The criterion condition testing was done on the third day. On this day, the subjects were tested for a single 1-hour session in which one complex task was presented for the first 30 minutes and the other was presented for the final 30 minutes. Thus, data were obtained on each task from a total of four conditions: simple-task performance on Day 1 and Day 2 and complex performance on Day 2 and Day 3.

III. Results.

A. *Task Reliability*. Product moment correlation coefficients were computed to reflect the reliability of the various measures under the simple-task conditions (measures from Day 1 and Day 2) and under the complex conditions (measures from Day 2 and Day 3). The resultant reliability data are presented in Table 1.

TABLE 1. Reliabilities of Measures

	Simple Condition	Complex Condition
Green Lights, Response Time	.639	.612
Red Lights, Response Time	.814	.484
Arithmetic % Correct	.692	.831
Arithmetic, Time/Problem	.804	.747
Problem Solving, Time/Response Solution Phase	.550	.566
Problem Solving, % Correct Confirmation Phase	.596	----
Problem Solving, Time/Response Confirmation Phase	----	.279
Meter Monitoring	.425	.501
Pattern Identification % Correct	.478	.669
Pattern Identification Time/Problem	.723	.218
Tracking Vector RMS Error	.502	.758

For 38 d.f., $r_{.05}=.325$ and $r_{.01}=.418$

With the exception of one of the problem-solving measures, all of the reliability coefficients for the simple conditions were significant at the .01 level or better. In the case of the complex conditions, 3 of the 11 coefficients were not significant; 2 of these nonsignificant reliabilities were for problem-solving measures and the third was for the pattern discrimination time measure.

B. *Practice and Task-Complexity Effects*. The evaluation of practice effects and the effect of task complexity was carried out in analyses of variance (treatments x treatments x subjects) applied to each task measure and condition;[21] thus, in all, 11 analyses were carried out. In these analyses, the data from the training session and from the Day 2 simple performance were considered to represent two diffeernt levels of practice on the simple-task-performance condition. Day 2 complex performance and the criterion session (Day 3) represented two levels of practice for the complex-performance condition. The mean scores for each measure are presented in Table 2 for each level of practice and task complexity. In regard to the complexity variable, all measures except problem-solving-confirmation accuracy showed that performance was significantly better under the simple-task con-

dition. A significant practice effect was found for 7 of the 11 measures; the exceptions were response time and response accuracy on problem-solving-confirmation performance, meter response time, and pattern-identification response time. There was a significant interaction between task complexity and practice on both the red and green lights measures. Inspection of the simple effects on these two measures showed that there was a significant practice effect between the two complex-performance sessions but not between the simple-task sessions.

TABLE 2. Mean Performance by Task Complexity and Practice

	Task Complexity		Practice Session	
	Simple	Complex	First	Second
Light Monitoring				
Green response time*	**1.39	6.47	4.38	3.51
Red response time	1.01	2.85	2.26	1.60
Arithmetic				
Percent correct	.70	.58	.59	.68
Time/problem	10.14	10.89	10.79	10.29
Problem Solving				
Solution, time/response	1.88	2.28	2.21	1.95
Confirmation, percent correct responses	.93	.88	.91	.90
Confirmation, time/response	1.57	2.01	1.81	1.78
Meter Monitoring				
Response time	12.53	23.19	18.28	17.41
Pattern Identification				
Percent correct	.90	.80	.83	.87
Time/problem	9.72	10.14	9.98	9.89
Tracking				
Vector RMS error (arbitrary units)	6.64	7.11	6.33	5.42

*All time measures are in seconds; recorded as 1/100 of a second.
**Underlined pairs differ at $p < .05$.

The relative contributions of the effects of practice and task complexity were evaluated for each measure exhibiting a significant effect by use of the omega-squared statistic, which provides an estimate of the proportion of total variance that is attributable to each effect.[18] The omega-squared statistics, which are presented in Table 3, show that although the practice effect is significant for seven measures, that effect is relatively small in magnitude; it accounts for no more than 5 percent of the total variance for any measure. The task-complexity effect, which is significant on 10 of the 11 measures, is in every case larger than the practice effect. The magnitude of the effect of complexity varies widely between measures, ranging from 6 to 71 percent of the total variance for a given task measure. The proportions of variance for those tasks that are most affected by task complexity are: green lights, 71 percent; red lights, 40 percent; tracking, 24 percent; and meters, 20 percent.

TABLE 3. Omega^2 *Estimate of Magnitude of Effect of* Significant Complexity and Practice Effects

	Complexity	Practice	Interaction
Light Monitoring			
Green response time	.71	.02	.02
Red response time	.40	.05	.05
Arithmetic			
Percent correct	.06	.04	
Time/problem	.07	.04	
Problem Solving			
Solution, time/response	.09	.04	
Confirmation, percent correct responses	n.s.	n.s.	
Confirmation, time/response	.06	n.s.	
Meter Monitoring	.20	n.s.	
Pattern Identification			
Percent correct	.14	.02	
Time/problem	.06	n.s.	
Tracking			
Vector RMS error (arbitrary units)	.24	.03	

C. *Factor Analytic Findings.* The data used in the factor analyses were based on the averages across the two trials for each measure at a given level of complexity. In all of the analyses, the principal components method was used with unity in the major diagonal. Following the rule suggested by Guttman[17] and Kaiser,[19] factors were extracted in a step-wise procedure until a factor with a eigenvalue of less than one was obtained. All factors with an eigenvalue greater than one were then rotated to simple structure by the normal varimax method. The measure identification key used in each of the remaining tables is shown in Table 4.

TABLE 4. Number Key for Measures

	Measure Number	
	Simple	Complex
Green Lights, Response Time	1	12
Red Lights, Response Time	2	13
Arithmetic % Correct	3	14
Arithmetic, Time/Problem	4	15
Problem Solving		
Solution Phase, Time/Response	5	16
Confirmation Phase, % Correct Response	6	17
Confirmation Phase, Time/Response	7	18
Meters, Response Time	8	19
Pattern Identification, % Correct	9	20
Pattern Identification, Time/Problem	10	21
Tracking, Vector RMS Error	11	22

The first analysis was applied to the measures from all tasks; there was a total of 11 measures for each of the two conditions of complexity. The results of this analysis are presented in Table 5; in this and the subsequent factor loadings tables, those loadings that exceeded .60 are marked with an asterisk for ease of reference. The correlation matrix on which the analyses are based is shown in Table 6. A total of seven factors were extracted.

The first factor extracted showed the largest loadings for the red and green lights under the simple condition, one of the problem-solving measures for the simple condition, and the pattern-discrimination time measure under both the simple and complex conditions. The second factor showed the largest loadings for the arithmetic task for both complexity conditions and for both speed and accuracy. The third factor showed the largest loading for the meters task under the simple condition and a slightly smaller loading for the problem-solving task, percent measure, during the confirmation phase under the simple condition. The fourth factor showed large loadings for only the tracking task under both the simple and complex conditions. The fifth factor showed loadings for the problem-solving time measures for both complexity conditions and for both solution and confirmation phases. The sixth factor showed the largest

TABLE 5. Factor Matrix for All Measures After Varimax Rotation

Measure Number*	Factor Number 1	2	3	4	5	6	7
1	* .88	-.08	.15	-.03	.02	.01	-.14
12	.36	-.07	.00	.03	-.01	*-.75	-.18
2	* .82	-.06	.21	-.07	-.25	-.11	-.12
13	.20	-.24	.22	.32	-.02	*-.70	.08
3	.20	*-.82	-.07	.08	-.01	-.02	.14
14	.05	*-.85	.12	.05	.08	.00	.02
4	.04	*-.69	-.06	.06	.02	-.27	-.43
15	-.12	*-.61	-.05	-.11	.02	-.32	-.48
5	.31	-.15	-.07	-.10	*-.80	.01	.08
16	-.11	.19	.02	-.04	*-.83	-.07	-.16
6	* .82	.06	-.14	.00	-.05	-.28	.21
17	-.35	-.22	*-.78	.06	-.10	.02	-.03
7	.50	.01	.05	.00	*-.65	.20	.26
18	-.17	.19	-.36	.35	*-.67	-.01	-.13
8	.02	.15	*-.87	-.04	.01	-.03	-.01
19	.04	-.03	-.17	-.23	.08	*-.79	.10
9	.34	-.09	-.49	.49	-.14	-.06	-.41
20	.33	-.01	-.06	.36	-.06	.13	*-.71
10	* .62	-.17	-.16	-.04	-.27	-.47	-.21
21	* .70	-.09	.13	-.14	.14	-.43	-.24
11	-.11	-.27	.04	* .85	.14	.01	.04
22	-.10	.15	-.02	* .87	-.10	.00	-.20
Eigenvalue	3.97	2.63	1.98	2.18	2.44	2.42	1.50
% of variance	.18	.12	.09	.10	.11	.11	.06

*See Table 4 for code.

TABLE 6. Correlation Matrix for All Measures

Measure Number*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2	.80																				
3	.12	.13																			
4	.22	.24	.52																		
5	.28	.42	.18	.08																	
6	.57	.46	.14	.00	.20																
7	.32	.41	.10	-.21	.54	.35															
8	-.06	-.04	-.07	.05	.11	.01	-.10														
9	.18	.09	.22	.27	.15	.29	.16	.19													
10	.50	.58	.21	.36	.40	.55	.25	.13	.36												
11	.03	-.05	.18	.30	-.11	-.16	-.16	.00	.20	-.13											
12	.33	.36	.18	.35	.08	.43	.02	.05	.26	.65	-.06										
13	.17	.35	.25	.39	.04	.25	.02	-.17	.19	.47	.22	.62									
14	.10	.07	.77	.60	.06	.03	-.07	-.21	.01	.17	.24	.10	.18								
15	.07	.02	.36	.83	-.02	-.07	-.17	-.07	.21	.31	.13	.39	.26	.52							
16	-.05	.16	-.15	-.04	.52	.05	.25	.09	.07	.18	-.12	.02	-.09	-.19	-.07						
17	-.32	-.27	.09	.16	.02	-.14	-.12	.32	.28	.05	.12	-.14	-.11	.02	.24	.06					
18	-.26	-.06	-.18	-.07	.38	-.07	.39	.28	.39	.10	.11	-.03	-.08	-.25	-.03	.47	.34				
19	.05	.08	.10	.21	.05	.28	-.21	.17	.03	.30	-.12	.61	.39	.04	.27	.00	.00	-.06			
20	.34	.30	.09	.32	.08	.05	.04	.05	.68	.28	.16	.21	.06	.03	.22	.08	-.06	.25	-.22		
21	.56	.48	.20	.21	.04	.48	.07	-.14	.16	.63	-.09	.53	.23	.16	.24	-.07	-.23	-.21	.41	.23	
22	-.11	-.12	-.11	.01	-.05	-.07	-.10	-.04	.37	-.01	.61	.02	.04	-.04	-.09	.17	.07	.41	-.21	.41	-.09

*See Table 4 for code.

loadings for the red and green lights under the complex condition and for the meter task also under the complex condition. The seventh factor had a large loading for only one measure —the meters task under the simple-performance condition.

In addition to the above analysis, separate factor analyses were carried out on the component measures of the Task A and Task B complex tasks. The first factor extracted in the analysis of the Task A measures (Table 7) was dominated by the four arithmetic task measures with loadings with respect to complexity and slightly higher loadings for arithmetic accuracy than for response time. The second factor showed the largest loadings on the red and green lights under the simple condition and on the problem-solving-confirmation-phase accuracy measure; note that the loadings for the simple and complex conditions in the case of the problem-solving measure are opposite in sign. The third factor showed the largest loadings on the problem-solving-task time measures for both solution and confirmation phases and for both simple and complex conditions. The fourth factor extracted showed large loadings on the red and green lights measures under the complex condition.

TABLE 7. Factor Matrix for Task A Measures After Varimax Rotation

Measure Number*	Factor Number 1	2	3	4
1	.14	* .85	.03	-.16
12	.06	.30	-.01	*-.86
2	.12	* .80	-.21	-.25
13	.13	.24	.06	*-.86
3	* .86	.14	.02	.00
14	* .86	.04	.15	.01
4	* .71	-.07	-.02	-.52
15	* .65	-.23	-.02	-.56
5	.20	.39	*-.75	.09
16	-.16	.01	*-.85	-.03
6	-.02	* .82	-.10	-.30
17	.25	*-.73	-.41	-.07
7	.00	.57	*-.62	.24
18	-.17	-.26	*-.81	-.06
Eigenvalue	2.62	3.34	2.58	2.32
% of variance	.19	.24	.18	.17

*See Table 4 for code.

Table 8 shows the factor loadings for the four factors extracted in the analysis of the Task B measures. The first factor showed loadings primarily on the pattern-identification-task accuracy measure for both levels of complexity. The second factor showed loadings for the meters task under the complex condition and the pattern-identification time measure under both complexity conditions. The third factor showed a large loading for only one measure—meters under the simple condition. The fourth factor showed large loadings for the tracking task for both levels of complexity.

TABLE 8. Factor Matrix for Task B Measures After Varimax Rotation

Measure Number*	Factor Number 1	2	3	4
8	.11	.01	* .86	-.01
19	-.37	*-.74	.32	-.01
9	* .88	-.17	.20	.23
20	* .94	-.04	-.06	.16
10	.46	*-.75	.08	-.15
21	.19	*-.82	-.24	.07
11	.01	.05	-.02	* .93
22	.39	.12	.01	* .84
Eigenvalue	2.21	1.83	.95	1.68
% of variance	.28	.23	.12	.21

*See Table 4 for code.

The final factor analysis, shown in Table 9, involved only the data from the monitoring tasks.

TABLE 9. Factor Matrix for Monitoring Task Measures After Varimax Rotation

Measure Number*	Factor Number 1	2	3
1	.07	* .94	-.01
12	* .90	.30	.05
2	.18	* .93	-.05
13	* .85	.20	-.39
8	.04	-.02	* .95
19	* .91	-.08	.28
Eigenvalue	2.40	1.89	1.14
% of variance	.40	.31	.19

*See Table 4 for code.

The first factor extracted showed large loadings under the complex conditions for all three monitoring measures; *viz.*, red lights, green lights, and meters. The second factor showed loadings for both the red and green lights under the simple condition and the third factor showed a large loading only for the meters task under the simple condition.

IV. Discussion.

The reliabilities of the measures were, in general, as good as could be expected considering the short test durations—15 minutes for each of the simple conditions and 15 minutes for the first and 30 minutes for the second complex condition. The near-zero coefficient for the problem-solving-confirmation time measure for the simple condition was probably a reflection of the fact that the variability on this measure was rather low, and much of the variability that did exist was attributable to the making of errors; the making of errors was essentially a chance event that resulted in nonsystematic variance across subjects. In fact, it is somewhat surprising that the error measure for the confirmation phase was as reliable as it appeared to be under the simple conditions, especially since it went to zero under the complex condition. As is seen in the factor loadings for these two measures, they do not represent a stable source of variance. The pattern-discrimination time measure dropped to a small nonsignificant value under the complex condition. This drop presumably was a direct result of the impact of the other simultaneously performed tasks; if the subjects had been giving proper attention to the remaining tasks, then they would not have been able to concentrate on the pattern-discrimination-task display and produce responses in the same stable relation to the onset of the second comparison pattern as they did under the simple condition.

The results of the analyses of variance showed clearly that task complexity was a substantially more important variable than practice as regards the relative contributions of these two variables to the total variance. The results also suggested that task complexity was less a factor on those tasks that demanded moment-by-moment involvement of the subject. Specifically, the arithmetic, pattern-identification, and problem-solving tasks were less influenced by task complexity than were the monitoring and tracking tasks. This general finding would be predicted by the secondary-task approach to workload measurement if we made the very reasonable assumption that the active tasks tend to be treated as primary tasks and the monitoring tasks, as secondary tasks. The tracking task is perhaps a case by itself. The nature of this task is such that any diversion of attention would be expected to result, on the average, in a decrement in performance. Therefore, the overall demands of complex Task B would likely lead the subject to adopt a strategy of accepting some amount of error on that task. Thus, the other tasks of complex B would require the subject to look away from the tracking task, and, as a result, increases in the tracking error measure would be expected. The results with respect to the complexity variable are of interest primarily because we can infer that those tasks to which complexity contributes a small amount of variance would be less likely to reveal time-sharing properties. Hence, the

monitoring and tracking measures would appear to be the most likely to exhibit evidence of a time-sharing ability.

It should be noted that, although the problem-solving task was presented both by itself and as a part of complex Task A, it is a group-performance task in the literal sense. Therefore, since it would quite likely be subject to group influences, it should be regarded primarily as a source of increased workload for the purposes of this study.

The results of the factor analysis for the entire set of measures can be readily interpreted as providing direct support for the hypothesis that there is a time-sharing ability that is involved in complex performance. Specifically, three orthogonal factors involving the monitoring tasks emerged: red and green lights performance loaded under the simple condition on one factor; meters performance loaded under the simple condition on another factor; and meters and lights performances both loaded on a third factor under the complex condition. The specific performance requirements of the meter monitoring task under the simple condition were identical to those of the complex condition, and the same was true of the red and green lights monitoring task. Thus, it seems reasonable to interpret the fact that these tasks are orthogonal under simple conditions but related under complex conditions as evidence of a higher-order process. It also seems quite reasonable to interpret that high-order process to be a reflection of differences in the ability of subjects to shift attention quickly and efficiently from the active tasks to the monitoring.

The factor analyses that were applied separately to the Task A and Task B data did not appreciably alter the general nature of the findings of the overall analysis. In each of these analyses, the factors on which the monitoring tasks were found to load under the simple condition were orthogonal to the factor on which they loaded under the complex condition. The findings of the fourth analysis, which involved only the monitoring data, were directly analogous to those of the overall analysis; there emerged two simple condition factors, one for lights and one for meters, and one complex condition factor on which meters and lights loaded. Whether one chooses to call the factor for the complex condition *complex monitoring ability* or *time-sharing ability* is perhaps arbitrary, but the results suggest a factor that clearly fits our proposed definition of a time-sharing ability—a source of variance for complex performance that is orthogonal to the implicated measures for simple performance.

An important aspect of this study was what was *not* found; namely, no complex performance factor emerged that could be called a Task A factor or a Task B factor, nor was there a factor that crossed over the two tasks as a general complex performance factor. Only the monitoring tasks appeared to have properties that warrant an inference about time sharing.

The best explanation for this general pattern devolves from a consideration of the notion of task priorities. Subjects appear to develop a hierarchical response strategy in which performance of a given (higher priority) task is protected at the expense of lower priority tasks. We have been generally aware of this for some time in an observational sense, and we have data from previous studies that seem to be best interpreted in this manner. For example, Chiles and Jennings[6] conducted a study on the effects of alcohol on complex performance. It was found that, with average blood alcohol levels on the order of 100 mg%, tracking and monitoring performance showed significant degradation but mental arithmetic performance was not affected. The nature of the arithmetic task was that the most reasonable explanation of those findings was that the subjects had "protected" their performance of the arithmetic task, presumably by devoting more of their attention to it. Therefore, our interpretation of these findings was that arithmetic performance was maintained at the expense of the performance of the other tasks.

If the subjects in the present study are assumed to be operating with some sort of response hierarchy, then it is reasonable to argue that the performance of the higher priority tasks under both the simple and the complex conditions would be primarily a function of the skill levels of the subjects on those tasks. From this it would follow, then, that performance of the lower priority tasks (presumably the monitoring

tasks) under the complex conditions would be primarily a function of the ability of the subject to shift attention from a higher priority task to scanning and detecting signals on the lower priority tasks. The results of the factor analyses clearly suggest that the skills that are important in the simple situation are also those that are of primary importance in the complex situation in the case of the arithmetic, pattern-discrimination, and (at least during the initial solution phase) problem-solving tasks. The results relating to these active tasks also clearly suggest that the findings for the monitoring tasks were not simply some sort of complementary process in which subjects who were better, for example, on the arithmetic task simply had more time to scan the monitoring displays. The orthogonality of the active task and monitoring task factors suggest that the skills underlying the performance of these two types of tasks are independent.

The extent to which the tasks used in this study may or may not yield "factorially pure" measures of fundamental abilities is only an academic concern. These tasks were selected originally because, and the rationale for their continued use is, they were judged to measure behavioral functions of relevance to complex performance as it is found in operational aviation systems. The content validity of these tasks has been confirmed by a large number of operational personnel. For this reason, it is of no particular concern that, for example, the pattern-discrimination-response time measure loads on the same factor as the red and green lights measure under the simple condition in the overall analysis and on the factor on which the meters task loads under the complex condition in the analysis of the Task B measures. It will be noted that there was ambiguity in the loadings of the pattern-discrimination time measure in the overall analysis; it had rather large loadings on the first factor for both complexity levels, but it also had moderate loadings for the complex-monitoring (time-sharing) factor, factor 6. It should also be noted that the measure of accuracy in the problem-solving task, confirmation phase, is rather unstable, presumably because there is very little variance on this measure; most subjects make very few errors in entering the second solution.

Although this type of study requires replication before final acceptance of the validity of the concept of time-sharing is warranted, there are, nonetheless, some important implications of these findings for research methodology. The findings strongly support an argument we have presented elsewhere:[2 3 5 6] if the goal of a research effort is generalization to complex operational tasks, then the tasks used must involve an element of complexity analogous to the time-sharing demands characteristic of the target operational situation.

In this regard, the "time-sharing ability" identified in our study is clearly related to the "divided-attention ability" referred to by North and Gopher[22] in interpreting their results on the prediction of success in flight training. The findings are also quite compatible with the argument that complex tasks are more likely to be sensitive to environmental and procedural variables than are simple tasks. The findings suggest that selection and screening programs for complex jobs, such as air traffic control, might very well be improved by the incorporation of suitable measures that tap time sharing as a basic ability. Furthermore, these findings provide indirect support for the use of secondary tasks to assess the workload properties of primary tasks.

V. Summary and Conclusions.

It has long been held that people differ with respect to their ability to master complex jobs. In the operational context, this ability is often referred to as though it represented variations in the facility with which people can simultaneously perform two or more tasks in a "time shared" manner. However, the existence of such an ability has never been quantitatively verified. This study attempted to determine whether such an ability could be isolated that is specific to proficiency in complex performance. For the purpose of this study, and within the context of the tasks employed, *time-sharing ability* was defined as "a reliable source of variance that contributes to performance of complex tasks but is independent of simple task performance of the constituent tasks."

Thirty-nine subjects were tested on two sets of performance tasks. Each set consisted of three individual tasks that could be presented in isolation for a simple-task-performance condition or in combination for a complex-performance condition. All of the subjects were tested on both sets of tasks in two sessions of simple-task performance and two sessions of complex-task performance.

A factor analysis revealed a single factor associated with performance of two monitoring tasks (lights and meters) under the complex condition, whereas simple performance of these tasks was represented by two separate factors. The factor that had high loadings on the monitoring tasks in the complex-task situations may reasonably be interpreted to be reflective of the existence of a time-sharing ability or skill. At the levels of complexity, difficulty, and training used in this study, the time-sharing factor was apparently not important in the performance of active, more demanding tasks. We suggest that the best explanation of the findings is that subjects tend to develop a response strategy that results in their "protecting" their performance of the active tasks. Thus, the hypothesized ability is revealed in the ease with which the subjects can shift attention from the active tasks to the less demanding monitoring tasks.

An important methodological implication of this study is that if research results are to be generalized to complex jobs such as those found in aviation operations, then the research tasks should exhibit an analogous level of complexity. The findings suggest that selection and screening programs for complex jobs, such as air traffic control, would be improved by the use of suitable measures that tap time sharing as a basic ability.

References

1. Bartlett, F. C.: The Measurement of Human Skill, BRITISH MEDICAL JOURNAL, 4510:835–838 and 4511:877–880, 1947.
2. Chiles, W. D.: Methodology in the Assessment of Complex performance: Introduction, HUMAN FACTORS, 9:325–327, 1967.
3. Chiles, W. D: Methodology in the Assessment of Complex Performance: Discussions and Conclusions, HUMAN FACTORS, 9:385–392, 1967.
4. Chiles, W. D., E. A. Alluisi, and O. S. Adams: Work Schedules and Performance During Confinement, HUMAN FACTORS, 10:143–196, 1968.
5. Chiles, W. D., P. F. Iampietro, and E. A. Higgins: Combined Effects of Altitude and High Temperature on Complex Performance, HUMAN FACTORS, 14:161–172, 1972.
6. Chiles, W. D, and A. E. Jennings: *Effects of Alcohol* on Complex Performance, HUMAN FACTORS, 12:605–612, 1970.
7. Chiles, W. D., A. E. Jennings, and G. West: Multiple Task Performance as a Predictor of the Potential of Air Traffic Controller Trainees. FAA Office of Aviation Medicine Report No. AM–72–5, 1972.
8. Conrad, R.: *Missed Signals in a Sensorimotor Skill*, JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 48:1–9, 1954.
9. Conrad, R.: Adaptation to Time in a Sensorimotor Skill, JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 49:115–121, 1955.
10. Conrad, R.: Timing, OCCUPATIONAL PSYCHOLOGY, 29:3, 1955.
11. Conrad, R.: The Timing of Signals in Skill, JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 51:365–370, 1956.
12. Fleishman, E. A.: The Prediction of Total Task Performance From Prior Practice on Task Components, HUMAN FACTORS, 7:18–27, 1965.
13. Fleishman, E. A.: *Performance Assessment* Based on an Empirically Derived Task Taxonomy, HUMAN FATORS, 9:349–366, 1967.
14. Fleishman, E. A.: On the Relation Between Abilities, Learning, and Human Performance, AMERICAN PSYCHOLOGIST, 27:1017–1032, 1972.
15. Fleishman, E. A., and S. Rich: Role of Kinesthetic and Spatial-Visual Abilities in Perceptual-Motor Learning, JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 66:6–11, 1963.
16. Freedle, R. O., A. N. Zavala, and E. A. Fleishman: Studies of Component-Total Task Relations: Order of Component-Total Task Performance and Total Task Predictability, HUMAN FACTORS, 10:283–296, 1968.
17. Guttman, L.: Some Necessary Conditions for Common-Factor Analysis, PSYCHOMETRIKA, 19:149–161, 1954.
18. Hayes, W. L.: *Statistics for the Social Sciences, Second Edition*, New York, Holt, Rinehart, and Winston, 1973.
19. Kaiser, H. F.: The Application of Electronic Computers to Factor Analysis, EDUCATIONAL AND PSYCHOLOGICAL MEASUREMENT, 20:141–151, 1960.
20. Knowles, W. B.: Operator Loading Tasks, HUMAN FACTORS, 6:155–161, 1963.
21. Lindquist, E. F.: *Design and Analysis of Experiments in Psychology and Education*, Houghton Mifflin Company, 1953.
22. North, R. A., and D. Gopher: Measures of Attention as Predictors of Flight Performance, HUMAN FACTORS, 18:1–14, 1976.
23. Parker, J. F.: Use of an Engineering Analogy in the Development of Tests to Predict Tracking Performance. Matrix Corporation report prepared for the Office of Naval Research under Contract NONR–3065(00), 1964.
24. Parker, J. F., and E. A. Fleishman: Ability Factors and Component Performance Measures as Predictors of Complex Tracking Behavior, PSYCHOLOGICAL MONOGRAPHS, 74:N503, 1960.
25. Rolfe, J. M.: The Secondary Task as a Measure of Mental Load. *In* Singleton, W. T., J. G. Fox, and D. Whitfield (Eds.), *Measurement of Man at Work*, London, Taylor and Francis, 1971.
26. Senders, J. W.: The Estimation of Pilot Workload. Unpublished Manuscript, 1967.

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Thirty-nine men were tested on a total of six tasks; performance was measured on each task presented individually and on two complex tasks made up of three-task subsets. The tasks measured monitoring, arithmetic, pattern-discrimination, tracking, and problem-solving performance. Two separate test sessions were conducted for each of the individual tasks and for each of the two complex tasks.

Factor analyses were performed on the resultant data to determine if there would emerge a time-sharing ability, defined as a reliable source of variance associated with complex performance but independent of simple-task performance of the constituent tasks. A factor was found that showed high loadings for two different monitoring tasks for complex performance but negligible loadings for these tasks for simple performance; separate independent factors were found for the two monitoring tasks when they were performed under simple-task conditions. The monitoring measures appear to possess properties that would be expected of measures of a time-sharing ability. The findings suggest that a suitable measure of time-sharing ability would be of value in the selection and screening of candidates for complex jobs.

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